the heat engine **614** converts from thermal energy of the hot region **618** and the cold region **620**.

[0157] The longitudinal nature of the heat engine **614**, along with the ability to have multiple contractions and expansions of the SMA member **622** allow the heat engine **614** to be used in large applications to produce more significant power output from the energy harvesting system **610**. The SMA member **622** may be formed as a large belt of solid SMA wires, SMA springs, or a matrix wire or springs to further enable scale-up of the heat engine **614**.

[0158] The heat engine **614** may also include timing mechanisms (not shown) to provide mechanical coupling and synchronization between the driven elements. A thermal barrier (not shown) may be used to prevent heat from passing from the hot region **618** to the cold pulleys **640**. Alternatively, the distance between the cold pulleys **640** and the hot region **618** may be sufficient to maintain the temperature differential in the SMA member **622** necessary to cause the phase change and produce mechanical energy from the available thermal energy.

[0159] Referring now to FIG. **11**A and FIG. **11**B, and with continued reference to FIGS. **1-10**, there is shown an energy harvesting system **710** and an energy harvesting system **750**. A plurality of heat engines are configured to capture thermal energy from high-aspect-ratio heat sources, such as pipes. Features and components shown and described in other figures may be incorporated and used with those shown in FIGS. **11**A and **11**B.

[0160] As shown in FIG. **11**A, a plurality of heat engines **714**, which may be similar to the heat engine **14** shown in FIG. **2**, the heat engine **614** shown in FIG. **10**, or other heat engines capable of longitudinal orientation, are arrayed longitudinally with the length of a hot region **718**, which may be a pipe carrying hot fluids. The heat engines **714** extend radially outward from the hot region **718** into a cold region **720**, which may be ambient air.

[0161] Additional heat engines **714** may be included in the energy harvesting system **710**, such that the heat engines **714** substantially surround the entire radius of the hot region **718**. The heat engines **714** extract thermal energy from the temperature differential between the hot region **718** and the cold region **720** and convert it to mechanical energy, which is transferred to a driven component (not shown) that utilizes or stores the mechanical energy.

[0162] As shown in FIG. **11**B, one or more first heat engines **754**—which may be similar to the heat engines **14** and **54** shown in FIGS. **2** and **3**, or may be other heat engines capable of longitudinal orientation—are arrayed adjacent to a hot region consisting of hot fluids **758**. In this configuration, the hot region is a pipe carrying the hot fluids **758**, such as the hot working fluids of a power generator.

[0163] The first heat engines **754** extend radially outward from the hot fluids **758** into a cold region consisting of cold fluids **760**. The cold fluids **760** shown in FIG. **11**B are within another pipe or another constrained pathway. In FIG. **11**B, the pipe containing the cold fluids **760** substantially encloses the pipe carrying the hot fluids **758**. However, the cold fluids **760** need not substantially enclose the heating source and may simply be adjacent. The cold fluids **760** may be supplied as moving ambient air via fans for blowers, or may be cooled fluids, such as from geothermal cooling.

[0164] The energy harvesting system **750** also includes one or more second heat engines **755** and one or more third heat engines **756**. The second heat engines **755** are placed longitudinally downstream, relative to flow of the hot fluids **758**. The third heat engines **756** are placed further downstream.

[0165] Additional heat engines may be included in the energy harvesting system **750** to substantially surround the radius of the pipe carrying the hot fluids **758**. Therefore the first, second, and third heat engines **754**, **755**, **756** may be capable of very efficient conversion of thermal energy from the hot fluids **758** by conduction heating and from the cold fluids **760** by convection cooling.

[0166] The energy harvesting system **750** is arranged for counter-flow between the hot fluids **758** and the cold fluids **760**, such that the hold fluids **758** and the cold fluids **760** flow in opposing directions through the system. This counter-flow arrangement means that the first heat engines **754** are exposed to higher temperatures of the hot fluids **758** than the third heat engine **756**. However, the first heat engines **754** are also exposed to relatively warmer temperatures of the cold fluids **760** than the third heat engines **756**, which are nearer the inlet of the cold fluids **760**.

[0167] The pipe carrying the hot fluids **758** may be insulated from the cold fluids **760**, such that no direct heat transfer occurs between the hot fluids **758** and the cold fluid **760**. Therefore, substantially the only heat transfer occurs between the hot fluids **758** and the first, second, and third heat engines **754**, **755**, **756** and between the first, second, and third heat engines **754**, **755**, **756** and the cold fluids **760**.

[0168] The first, second, and third heat engines **754**, **755**, **756** interact with the cold fluids **760** at a first cold temperature, a second cold temperature, and a third cold temperature, respectively. Because the cold fluids **760** enter the energy harvesting system **750** near the third heat engine **756**, the third cold temperature is the coldest of the three points. However, as the third heat engine **756** expels heat to the cold fluids **760**, the temperature of the cold fluid **760** increases. Therefore, the second cold temperature is greater (hotter) than the third cold temperature and the first cold temperature is greater than the second cold temperature.

[0169] Therefore, the temperature differential between the adjacent hot fluids **758** and the adjacent cold fluids **760** experienced by the first heat engine **754** may be similar to the temperature differential experienced by the third heat engine **756**. That is, the differential between the first hot temperature and the first cold temperature used by the first heat engine **754** is similar to the differential between the second hot temperature and the second cold temperature used by the second heat engine **755**.

[0170] Each of the first, second, and third heat engines **754**, **755**, **756** interacts with similar temperature differentials and may therefore have similar power output. This is contrary to direct-flow arrangements (where the hot and cold fluid flow in the same direction), which have a large temperature differential at the entrance (for the first heat engines **754**, in this example) to the system and much smaller temperature differentials at the exit (for the third heat engines **756**, in this example).

[0171] Referring now to FIG. **12**, and with continued reference to FIGS. **1-11**B, there is shown an SMA member **822**, which may be used with large-scale heat engines. The SMA member **822** is a round, three-dimensional SMA working element. Features and components shown and described in other figures may be incorporated and used with those shown in FIG. **12**.

[0172] The SMA member **822** includes a plurality of SMA strands **823**, which may be SMA wires, strips, or another